GEOGRAPHIC VARIATION IN THE LEAF ESSENTIAL OILS OF *JUNIPERUS GRANDIS* (CUPRESSACEAE) II.

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ABSTRACT

The volatile leaf oils of *J. grandis* in California were analyzed from throughout its range. A clinal trend was found northward from the High Sierras to Stampede Meadows and thence to Beckwourth. The Beckwourth oil, although most similar (0.745) to *J. grandis* from the High Sierras, had a 0.728 similarity to *J. occidentalis* (Yolla Bolly Mtns.). The oils in the Beckwourth population are intermediate between *J. grandis* and *J. occidentalis* indicating hybridization. A northward clinal pattern of higher similarities of *J. grandis* to *J. occidentalis* is suggestive of past introgression. The San Bernardino Mtns., *J. grandis* populations' oils were more similar to *J. occidentalis* (0.743), than to *J. grandis* at nearby 9 Mile canyon (0.540). Confounding the situation, DNA analyses, grouped the San Bernardino Mtns. juniper with *J. osteosperma*. *Phytologia 94(1): 3-21 (April 2, 2012).*

KEY WORDS: *Juniperus grandis (= J. occidentalis* var. *australis), J. californica, J. occidentalis, J. osteosperma,* Cupressaceae, terpenes, geographic variation.

Previously, Adams and Kauffmann (2010a) reported on geographic variation in the leaf essential oils of *J. grandis* R. P. Adams (= *J. occidentalis* var. *australis* (Vasek) A. & N. Holmgren). They found (Fig. 1) that the leaf oils of *J. grandis* contained two chemical races: High Sierra populations with oils dominated by δ-3-carene (17.9-30.0%) and low in sabinene, and the San Bernardino Mtns. population with oil low in δ-3-carene, but very high in sabinene (24.3%). Adams and Kauffmann (2010a) found the leaf oil of putative *J. grandis* of the Yolla Bolly Mtns. was actually more similar to the oil of *J. occidentalis* than *J. grandis*. Subsequent DNA sequencing gave support that the Yolla Bolly Mtns. juniper is a divergent form of *J. occidentalis* (Adams and Kauffmann, 2010b; Adams 2011).

At the northern end of the range of *J. grandis*, populations appear to descend from the High Sierras (Fig. 2). Vasek (1966) felt that *J. grandis* (as *J. occ.* var. *australis*) intergraded into *J. occ.* var. *occidentalis* in the region north of the High Sierras. In my previous study (Adams and Kauffmann, 2010a) I did not sample from this region.

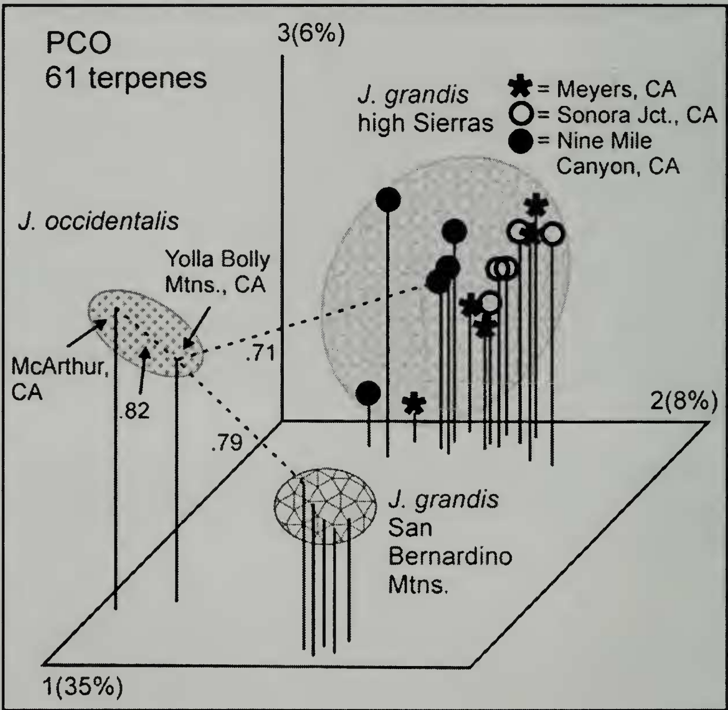

Figure 1. PCO based on 61 terpenes from *J. grandis* (20 individuals) and *J. occidentalis* populations (McArthur, Yolla Bolly Mtns., CA). The dotted lines are minimum links that connect the groups. The numbers by the dotted lines are the similarity (0.0 - 1.0 scale).

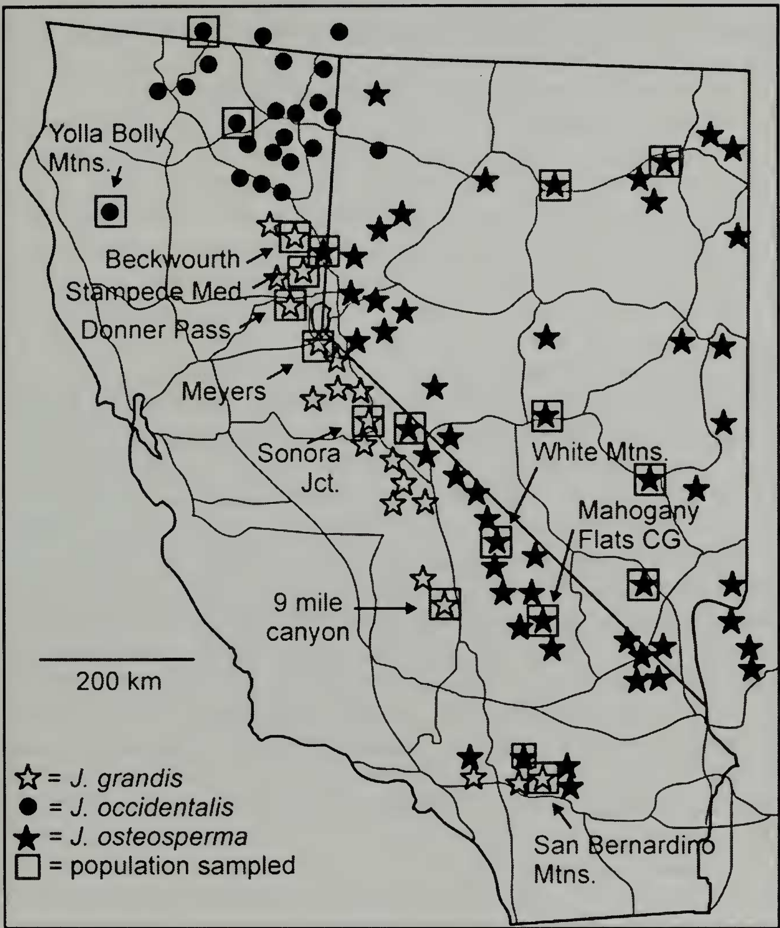

Figure 2. Distributions of *J. grandis*, *J. occidentalis* and *J. osteosperma*, modified from Vasek (1966) and Adams and Kaufmann (2010a). Note the northern-most populations of putative *J. grandis* sampled: Donner Pass, Stampede Meadows, and Beckwourth, CA.

In the present study, I report on analyses of populations of putative *J. grandis* from Donner Pass, Stampede Meadows, and Beckwourth, CA as a well as an additional population from Onyx

Summit, San Bernardino Mtns. where the 'purest' *J. grandis* is thought to grow (F. C. Vasek, personal communication).

MATERIALS AND METHODS

Plant material: *J. grandis, Adams 11963-11967*, Jct. US 50 & CA 89, 38° 51.086N, 120° 01.244'W, 1937 m, Meyers, El Dorado Co.; CA; *Adams 11968-11972*, 16 km w of Sonora Jct., on CA Hwy. 108, 38° 18.289'N, 111° 35.598'W, 2585 m, Tuolumne Co.; CA, *Adams 11984-11988*, Nine Mile Canyon Rd., 20 km w of Jct. with US 395, 35° 54.003'N, 118° 02.078'W, 2059 m, Tulare Co., CA; *Adams 11989-11993*, 5km n Big Bear City on CA 18, 34° 17.533'N, 116° 49.153'W, 2053 m, San Bernardino Co., CA; *J. grandis, Adams 11963-11967*, Jct. US 50 & CA 89, 38° 51.086N, 120° 01.244'W, 1937 m, Meyers, El Dorado Co.; CA; *Adams 11968-11972*, 16 km w of Sonora Jct., on CA Hwy. 108, 38° 18.289'N, 111° 35.598'W, 2585 m, Tuolumne Co.; CA, *Adams 11984-11988*, Nine Mile Canyon Rd., 20 km w of Jct. with US 395, 35° 54.003'N, 118° 02.078'W, 2059 m, Tulare Co., CA; *Adams 11989-11993*, 5km n Big Bear City on CA 18, 34° 17.533'N, 116° 49.153'W, 2053 m, San Bernardino Co., CA; *Adams 12319-12322,* Onyx Summit on CA 38, 34° 11.524'N; 116° 43.227' W.2600 m, San Bernardino Co., CA; *Adams 12328-12331, 12367,* Donner Pass Summit on old US50, 39° 18.999' N; 120° 19.581' W. 2180 m, Placer Co., CA; *Adams 12332-12336,* on Stampede Meadows Rd. (Co. rd 894Aa1t), 5 mi. n of I80. 39° 24.966' N; 120° 05.249' W, 1660 m, Nevada Co., CA; *Adams 12337-12341,* 4.7 mi. n of Beckwourth on Beckwourth-Genesee Rd., 39°52.433'N; 120° 24.345'W, 1770 m, Plumas Co., CA.

J. occidentalis, Adams 11940-11942, 12 km e of Jct. WA 14 & US 97 on WA 14, 45° 44.392'N, 120° 41.207'W, 170 m, Klickitat Co.; WA, *Adams 11943-11945*, 2 km s of jct. US 97 & US 197 on US 97, 38 km ne of Madras, OR; 44° 53.676'N, 120° 56.131'W, 951 m, Wasco Co., OR; *Adams 11946-11948*, 3 km sw of Bend, OR; on OR 372, 44° 02.390'N, 121° 20.054'W, 1132 m, Deschutes Co., OR; *Adams 11949-11951,* 32 km e of Bend, OR on OR 20, shrubs, 0.5 - 1m tall, 43° 53.922'N, 120° 59.187'W, 1274 m, Deschutes Co., OR; *Adams 11952-11954,* 14 km e of Jct. OR66 & I5, on OR66, 42° 08.044'N, 122° 34.130'W, 701 m, Jackson Co., OR; *Adams 11957-11959*, on CA299, 10 km e of McArthur, CA, 41° 05.313'N, 121° 18.921'W, 1091 m,

Lassen Co., CA; *Adams 11995-11998 (Kauffmann A1-A3, B1),* Yolla Bolly-Middle Eel Wilderness, 40° 06' 34"N, 122° 57' 59W, 1815- 2000 m, Trinity Co., CA, *Adams 12342-12346*, 19 km WSE of Susanville, CA, on CA 36, 40° 22.178'N, 120° 50.211' W, 1570 m, Lassen Co., CA, *Adams 12347-12351*, on US 395, 5 km n of Madeline, 41° 05.867'N, 120° 28.456' W, 1695 m, Lassen Co., CA.
J. osteosperma, Hancock Summit, mile 38 on US375, 37° 26.404'N, 115° 22.703'W, 1675 m, Lincoln Co. NV; *Adams 11125-11127*, McKinney Tanks Summit on US 6, 38° 07.005'N, 116° 54.103'W, 1933 m, Nye Co., NV. Voucher specimens are deposited in the Herbarium, Baylor University (BAYLU).

Isolation of Oils - Fresh leaves (200 g) were steam distilled for 2 h using a circulatory Clevenger-type apparatus (Adams, 1991). The oil samples were concentrated (ether trap removed) with nitrogen and the samples stored at -20°C until analyzed. The extracted leaves were oven dried (100°C, 48 h) for determination of oil yields.

Chemical Analyses - Oils from 10-15 trees of each of the taxa were analyzed and average values reported. The oils were analyzed on a HP5971 MSD mass spectrometer, scan time 1/ sec., directly coupled to a HP 5890 gas chromatograph, using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column (see Adams, 2007 for operating details). Identifications were made by library searches of our volatile oil library (Adams, 2007), using the HP Chemstation library search routines, coupled with retention time data of authentic reference compounds. Quantitation was by FID on an HP 5890 gas chromatograph using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column using the HP Chemstation software.

Data Analysis - Terpenoids (as per cent total oil) were coded and compared among the species by the Gower metric (1971). Principal coordinate analysis was performed by factoring the associational matrix using the formulation of Gower (1966) and Veldman (1967).

RESULTS AND DISCUSSION

The leaf oil of *J. grandis* from Donner Pass was quite similar to that of nearby Meyers, CA, High Sierra type oil (Table 1), being high in α-pinene, δ-3-carene, β-phellandrene, and very low in β-pinene. The leaf oil from nearby Stampede Meadows was very similar to the High Sierra oil (cf. Stamp vs. Meyers, Table 1). However, the leaf oil from Beckwourth was quite different from the High Sierra oils (cf. Meyers, Stampede Meadows and Beckwourth, Table 1). The Beckwourth trees have a number of components similar to *J. grandis*: p-cymene, β-phellandrene, p-menth-1,5-dien-8-ol isomer, terpinen-4-ol, m-cymen-8-ol, citronellol, piperitone, unknown 1388, γ-cadinene, and elemicin. Other compounds are similar to *J. occidentalis*: tricyclene, α-thujene, α-pinene, camphene, sabinene, and cis-sabinene hydrate. Intermediate concentrations and complemented terpenes would be expected in hybrids. It is interesting that the lower amounts of α-pinene and α-fenchene is similar to the oil of *J. occidentalis* (Table 1), but the high concentration of β-phellandrene (20.1%) is more like High Sierra, *J. grandis*.

The oils of *J. grandis* are differentiated into three groups (Fig. 3): the High Sierras group (including the sub-group of Donner Pass), Beckwourth, CA, and the San Bernardino Mtns. One individual from 9 Mile Canyon had an unusual oil profile and is only loosely clustered with other High Sierra trees (Fig. 3).

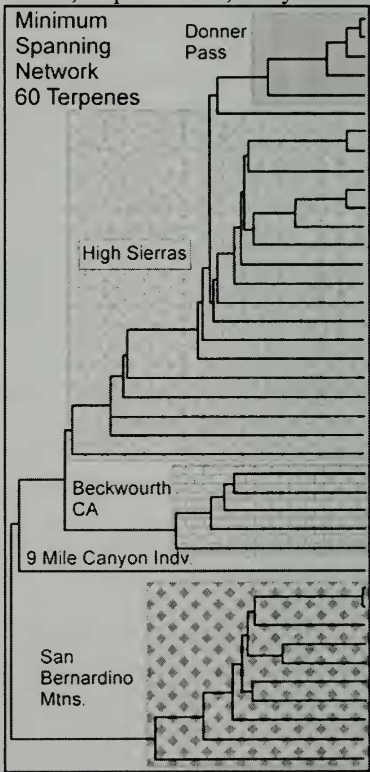

Figure 3. Minimum spanning network based on 60 terpenes.

Principal coordinates analysis (PCO) revealed additional perspectives (Fig. 4) among the groups. The Donner Pass oil is very similar to High Sierras oil (Fig. 4). As found in Table 1, the San Bernardino Mtns. oil is more similar to the Beckwourth oil than the oils from the High Sierras (Fig. 4).

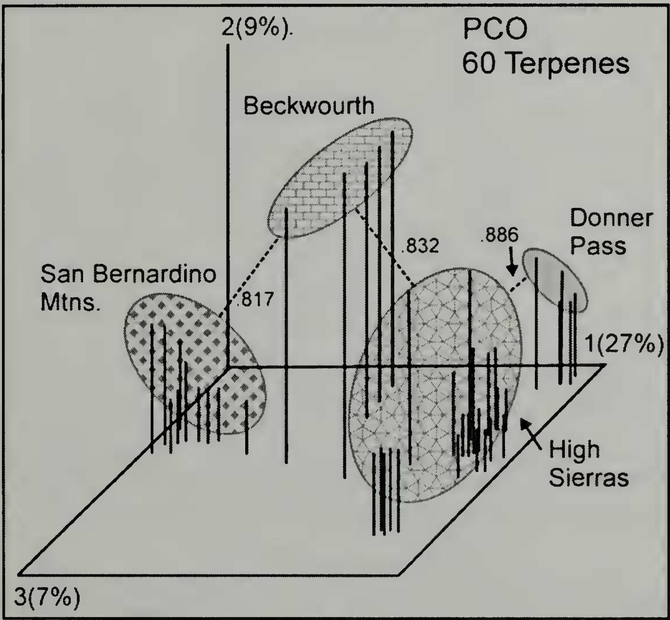

Figure 4. Principal Coordinates analysis (PCO) of 40 J. grandis oils based on 60 terpenes. The dashed lines are the linkage (similarity) between the four major groups.

A PCO using 63 terpenes with eight population average oils of *J. grandis,* plus two populations of *J. occidentalis* (McArthur and Yolla Bolly, CA) and two populations of *J. osteosperma* (McKinney Tanks and Hancock Summit, NV), shows (Fig. 5) the intermediate nature of the leaf oil from the Beckwourth population between Stampede Meadows and *J. occidentalis* (Yolla Bolly). The San Bernardino Mtns. population's oil is most similar to *J. occidentalis*, and more similar to the Beckwourth oil than to the High Sierras oil (Fig. 5, Table 1).

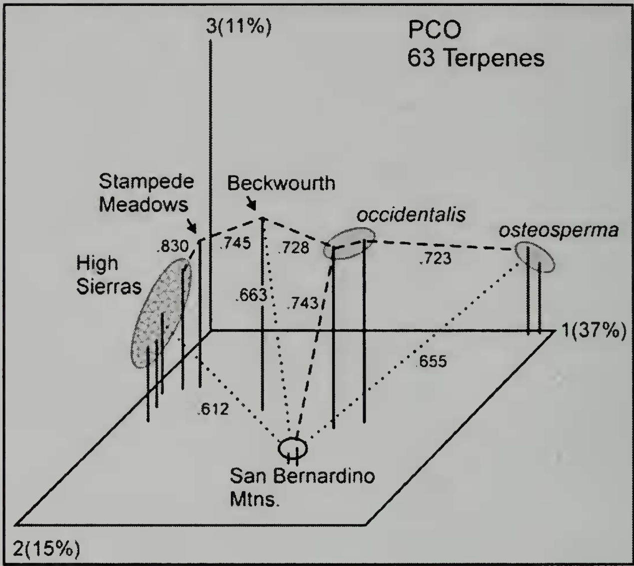

Figure 5. PCO based on 63 terpenes. The dashed lines are the minimum spanning network and the dotted lines show secondary links. The numbers near the lines are the similarities of the oils.

Contoured clustering (Fig. 6) shows the clinal nature of the variation in *J. grandis* from the High Sierras to the northernmost population (Beckwourth). The disjunct nature of the similarity between *J. occidentalis* (Yolla Bolly, McArthur) and the San Bernardino Mtns. (*J. grandis*) populations is apparent (Fig. 6).

Adams (1982), using morphological data from synthetic crosses in sunfish, and terpenoids in natural hybrids of *J. horizontalis* and *J. scopulorum*, compared a number of multivariate methods for the detection of hybridization. He found that Principal Coordinates (PCO) ordinated the parents on the first axis and the hybrids on the second axis, with backcrossed individuals between the parents and hybrids (Adams, 1982, Figs. 4, 9).

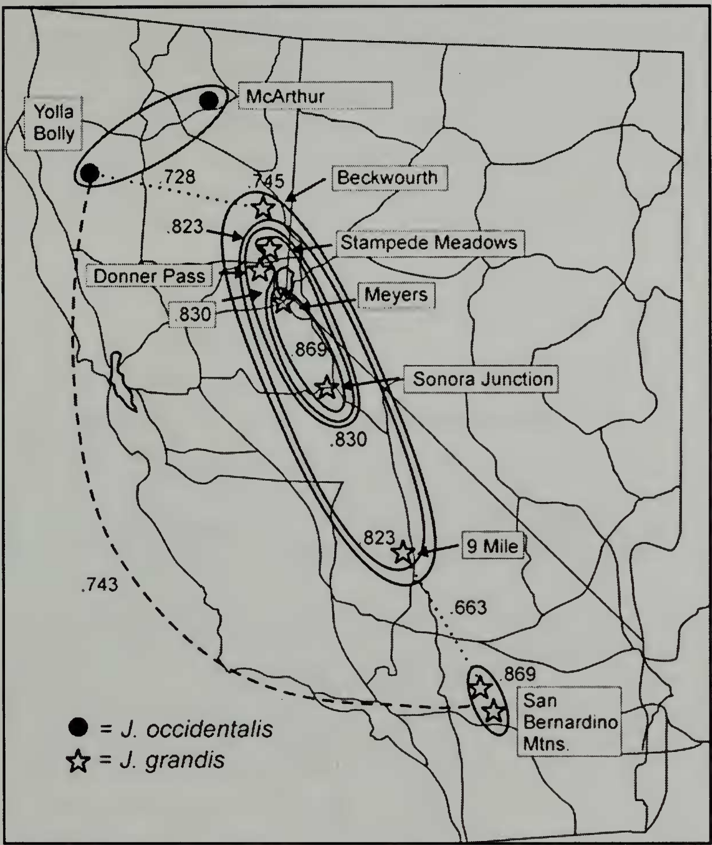

Figure 6. Contoured clustering based on 63 terpenoids. The dashed and dotted lines show unusual links. The numbers next the lines are the similarities.

PCO of *J. grandis* (Meyers, Sonora Junction) individuals from the Beckwourth and Stampede Meadows individuals, and ten populations of *J. occidentalis* accounted for 33% of the variance in PCO 1 (separating *J. grandis* and *J. occidentalis*, Fig. 7). PCO 2 (10% of variance) separates the Beckwourth individuals from *J. grandis* and *J. occidentalis*. As Adams (1982) found, the ordination forms a V shape, with the putative hybrids intermediate, but not on a line between putative parents (Fig. 7). Examination of Table 1, shows a number of compounds that are present in the Beckwourth trees that are found in one of the putative parents. The oils of the divergent trees from the Stampede Meadows population appear to differ little from typical *J. grandis* in this ordination. It should be noted that the bark on trees in the Beckwourth population was shaggy and gray with cinnamon beneath, not the typical cinnamon bark color as found in the High Sierras.

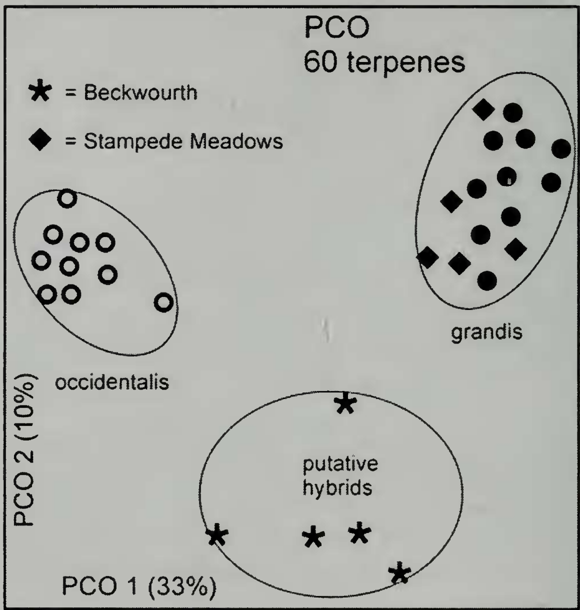

Figure 7. PCO based on 60 terpenes, ordinating *J. grandis, J. occidentalis* and putative hybrids from Beckwourth.

Another method to examine the clinal variation in *J. grandis* is by a linkage map among populations (Fig. 8). As one proceeds northward from Sonora Junction (Sj) to Meyers (My), to Donner Pass (Dp), Stampede Meadows (Sm) to Beckwourth (Bc) one finds progressively lower similarities (Fig. 8). However, the fact that similarities are lower as one proceeds from the central High Sierras

(My, Sj) to Sm and Bc does not necessarily imply introgression from *J. occidentalis*. Examination of the secondary links from *J. occidentalis* at Yolla Bolly (YB) show (Fig. 8) the highest similarity is to Beckwourth (Bc, .728), Donner pass (Dp, .701), Stampede Meadows (Sm, .650) and finally to the High Sierras (My, .630). This trend does appear to support introgression from *J. occidentalis* into *J. grandis*.

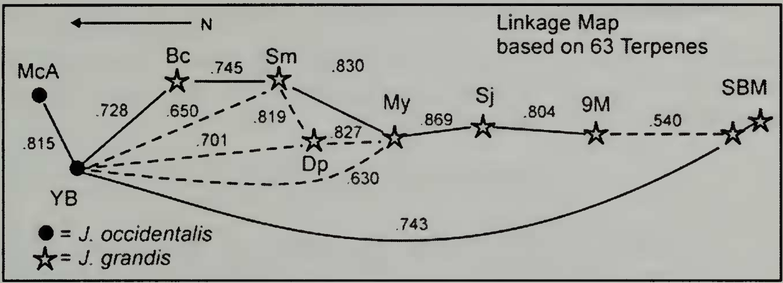

Figure 8. Linkage map based on 63 terpenes. The numbers next to the lines are the similarities. The dashed lines are secondary links.

The disjunct similarity between the *J. grandis* in the San Bernardino Mtns. and Yolla Bolly *(J. occidentalis)* is difficult to explain. Ancient hybridization and introgression could explain the pattern. Alternatively, if *J. occidentalis*-like individuals once extended much further southward along the Sierra Nevada foothills during the Pleistocene, then the population in the San Bernardino Mtns. could have been established and become isolated in more recent times. To confound the matter, DNA sequencing did not resolve putative *J. grandis* (San Bern. Mtns., Fig. 9) from *J. osteosperma* (Adams and Kauffmann, 2010b).

Thus, we are faced with conflicting data sets for the putative *J. grandis* from the San Bernardino Mtns. These trees' morphology (cinnamon-colored bark, leaves and females cones) is as found in the High Sierras, but the oils are very much more like *J. occidentalis,* and the cpDNA (so far) is not different from *J. osteosperma* (Fig. 9). Clearly the San Bernardino Mtns. *J. grandis* group presents an unusual situation that will require additional research to resolve.

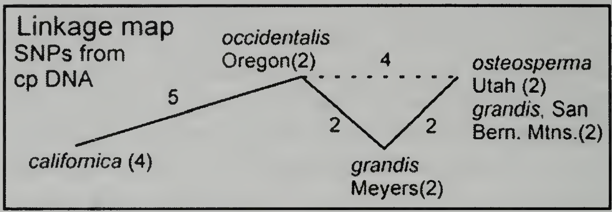

Figure 9. Linkage map based on SNPs from petN-psbM, trnD-trnT and trnG-trnG sequences (Adams and Kauffmann, 2010b). The numbers next the lines are the number of SNPs.

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Table 1. Leaf essential oil compositions for three populations of *J. grandis*, (Meyers, CA; Stampede Meadows, CA, Beckwourth, CA and Big Bear City, San Bernardino Mtns., CA) plus *J. occidentalis* (Yolla Bolly, Trinity Alps, CA, and McArthur, CA). Compounds in boldface appear to separate taxa and were used in numerical analyses. KI = Kovats Index (linear) on DB-5 column. *Tentatively identified. Compositional values less than 0.1% are denoted as traces (t). Unidentified components less than 0.5% are not reported. Those compounds that appear to distinguish taxa are in boldface.

KI	Compound	grandis Meyers	grandis Stamp	grandis Beckw.	grandis Big Bear	occid Trin Alp	occid Mc Art.
921	**tricyclene**	**-**	**-**	**0.1**	**0.3**	**t**	**1.1**
924	**α-thujene**	**-**	**-**	**0.4**	**2.3**	**1.8**	**1.0**
932	**α-pinene**	**14.0**	**6.8**	**2.5**	**7.1**	**5.1**	**5.0**
945	**α-fenchene**	**1.5**	**1.2**	**t**	**0.2**	**-**	**t**
946	**camphene**	**-**	**-**	**0.3**	**0.3**	**0.3**	**1.0**
953	thuja-2,4-diene	t	-	-	-	-	t
961	**verbenene**	**2.9**	**2.0**	**0.6**	**0.3**	**0.7**	**-**
969	**sabinene**	**-**	**t**	**10.7**	**24.3**	**20.4**	**12.0**
974	**β-pinene**	**1.3**	**0.8**	**0.6**	**0.5**	**0.7**	**0.4**
988	myrcene	3.1	3.4	3.5	1.7	3.0	1.3
1001	δ-2-carene	1.1	0.7	0.8	0.1	0.3	t
1002	α-phellandrene	1.6	1.6	4.0	0.4	1.2	0.8
1008	**δ-3-carene**	**27.3**	**17.0**	**1.6**	**2.8**	**4.4**	**1.0**
1014	α-terpinene	0.4	0.3	1.1	3.0	3.2	1.7
1020	**p-cymene**	**1.4**	**0.2**	**2.0**	**6.5**	**5.5**	**10.7**
1024	**limonene**	**1.2**	**t**	**t**	**1.6**	**0.7**	**0.9**

KI	Compound	grandis Meyers	grandis Stamp	grandis Beckw.	grandis Big Bear	occid Trin Alp	occid Mc Art.
1025	**β-phellandrene**	**10.6**	**16.1**	**20.1**	**1.5**	**6.7**	**3.5**
1044	(E)-β-ocimene	t	t	0.2	0.3	0.5	0.1
1054	**γ-terpinene**	**0.3**	**0.6**	**1.6**	**4.9**	**5.3**	**3.0**
1065	**cis-sabinene hydrate**	**-**	**-**	**0.5**	**1.9**	**1.2**	**0.9**
1086	terpinolene	3.7	2.3	1.7	1.9	2.4	1.3
1092	96, 109,43,152, C10-OH	0.9	1.2	-	-	-	-
1095	**trans-sabinene hydrate**	**-**	**-**	**0.4**	**1.8**	**t**	**0.7**
1095	linalool	t	0.7	0.5	-	1.5	0.5
1100	55,83,110,156, unknown	-	-	-	-	-	0.3
1102	isopentyl-isovalerate	-	-	-	-	-	-
1112	trans-thujone	-	-	-	0.2	-	t
1118	cis-p-menth-2-en-1-ol	0.8	1.7	2.7	0.7	1.0	0.7
1122	α-campholenal	t	-	-	-	-	-
1132	cis-limonene oxide (furanoid)	t	-	-	-	-	-
1136	trans-p-menth-2-en-1-ol	0.9	1.4	2.0	0.8	0.9	0.9
1141	**camphor**	**-**	**0.5**	**0.3**	**1.2**	**t**	**2.5**
1144	**neo-isopulegol**	**0.5**	**0.5**	**-**	**-**	**-**	**-**
1145	camphene hydrate	t	t	0.2	0.2	-	0.2
1154	**p-menth-1,5-dien-8-ol iso.**	**0.6**	**0.8**	**t**	**-**	**-**	**-**
1154	sabina ketone	-	-	t	0.9	0.3	0.4
1161	p-menth-1,5-dien-8-ol iso.	0.3	-	-	-	-	-
1165	borneol	-	-	-	0.1	t	2.2
1166	coahuilensol	t	0.7	1.2	-	2.4	0.6

KI	Compound	grandis Meyers	grandis Stamp	grandis Beckw.	grandis Big Bear	occid Trin Alp	occid Mc Art.
1174	**terpinen-4-ol**	**0.4**	**0.8**	**3.7**	**9.3**	**9.8**	**6.7**
1176	**m-cymen-9-ol**	**0.4**	**1.2**	**0.4**	-	-	-
1176	cryptone	-	-	t	-	-	-
1179	p-cymen-8-ol	0.4	1.1	0.2	1.0	0.9	0.5
1186	α-terpineol	1.2	0.3	-	0.3	0.5	0.4
1195	myrtenol	-	-	-	0.2	-	-
1195	cis-piperitol	0.4	0.6	0.6	0.2	0.1	0.2
1204	verbenone	-	-	-	-	-	-
1207	trans-piperitol	0.9	1.4	1.0	0.6	0.5	0.3
1215	trans-carveol	-	-	-	-	-	-
1219	coahuilensol, me-ether	0.4	1.7	1.5	-	2.7	1.1
1223	**citronellol**	**t**	**0.4**	**0.4**	**0.2**	-	**8.4**
1230	**trans-chrysanthenyl acetate**	**3.9**	**3.2**	**0.5**	**0.4**	-	-
1238	cumin aldehyde	-	-	-	0.3	0.7	0.2
1239	carvone	t	0.3	-	-	-	-
1249	piperitone	1.2	2.0	0.9	-	0.5	0.2
1253	trans-sabinene hydrate ac	-	-	-	0.6	-	-
1254	linalool acetate	-	-	-	-	0.1	0.1
1255	4Z-decenol	0.4	-	-	-	-	-
1257	methyl citronellate	0.2	0.2	-	0.1	-	-
1260	152,123,77,109, C10-OH	-	-	-	0.2	-	-
1274	neo-isopulegyl acetate	0.3	0.2	-	-	-	-
1283	α-terpinen-7-al	-	-	-	-	-	-

KI	Compound	grandis Meyers	grandis Stamp	grandis Beckw.	grandis Big Bear	occid Trin Alp	occid Mc Art.
1284	**bornyl acetate**	**0.4**	**0.8**	**5.2**	**2.2**	**t**	**9.5**
1285	**safrole**	**0.3**	**0.1**	**-**	**-**	**-**	**-**
1298	carvacrol	0.2	0.3	0.3	0.2	0.7	0.4
1298	3'-methoxy-acetophenone	-		-	0.2	-	-
1319	149,69,91,164, phenolic	0.8	-	-	-	-	-
1322	**methyl-geranate**	**-**	**1.4**	**16.3**	**1.8**	**0.8**	**1.0**
1325	p-mentha-1,4-dien-7-ol	-	-	-	0.7	0.1	t
1332	cis-piperitol acetate	0.4	-	-	-	-	-
1343	trans-piperitol acetate	0.3	-	-	-	-	-
1345	α-cubebene	-	-	-	t	t	t
1350	citronellyl acetate	-	-	-	-	-	-
1374	α-copaene	-	-	t	0.2	0.6	1.0
1387	β-bourbonene	0.5	-	-	0.3	t	0.2
1387	β-cubebene	-	-	-	-	-	-
1388	**79,43,91,180, unknown**	**0.3**	**0.3**	**0.1**	**-**	**0.1**	**-**
1389	**111,81,151,182, unknown**	**1.0**	**1.2**	**0.2**	**0.4**	**0.1**	**-**
1403	methyl eugenol	t	0.2	-	-	-	-
1417	(E)-caryophyllene	-	-	-	0.2	-	-
1429	cis-thujopsene	-	-	-	-	-	0.9
1430	β-copaene	-	-	-	t	-	-
1448	cis-muurola-3,5-diene	t	-	-	0.2	-	-
1451	trans-muurola-3,5-diene	-	-	-	-	0.1	0.1
1452	α-humulene	-	-	-	-	-	-

KI	Compound	grandis Meyers	grandis Stamp	grandis Beckw.	grandis Big Bear	occid Trin Alp	occid Mc Art.
1465	cis-muurola-4,5-diene	-	-	-	0.1	t	0.1
1468	pinchotene acetate	-	0.8	1.4	-	2.0	0.6
1471	**121,105,180,208,phenol**	**0.3**	**0.7**	**1.3**	**0.3**	**-**	**-**
1471	dauca-5,8-diene	-	-	-	0.2	-	-
1475	trans-cadina-1(6),4-diene	-	-	-	-	t	0.3
1478	**γ-muurolene**	**-**	**0.2**	**t**	**0.2**	**0.1**	**0.8**
1484	germacrene D	0.2	0.2	t	0.3	t	0.3
1491	43,207,161,222, C15-OH	-	-	-	0.3	-	-
1493	trans-muurola-4(14),5-diene	-	0.3	t	0.2	0.7	0.4
1493	epi-cubebol	-	0.4	0.2	0.5	0.4	0.4
1500	α-muurolene	0.3	0.3	t	-	0.6	1.1
1513	**γ-cadinene**	**1.3**	**0.6**	**0.3**	**1.2**	**1.8**	**3.7**
1518	epi-cubebol	0.4	1.2	0.4	1.5	t	0.4
1521	**trans-calamenene**	**-**	**0.6**	**t**	**2.3**	**-**	**-**
1522	δ-cadinene	1.1	0.7	0.8	-	2.2	4.1
1533	trans-cadina-1,4-diene	-	-	-	0.1	t	0.1
1537	α-cadinene	t	t	-	0.2	t	0.4
1544	α-calacorene	-	-	-	-	t	0.3
1548	elemol	-	0.1	0.7	0.9	-	-
1555	**elemicin**	**1.5**	**0.7**	**0.5**	**-**	**-**	**-**
1559	germacrene B	-	-	-	0.1	-	-
1561	**1-nor-bourbonanone**	**-**	**-**	**-**	**1.1**	**-**	**-**
1561	(E)-nerolidol	-	-	t	-	-	-

KI	Compound	grandis Meyers	grandis Stamp	grandis Beckw.	grandis Big Bear	occid Trin Alp	occid Mc Art.
1574	germacrene-D-4-ol	0.7	0.8	0.4	-	0.5	0.6
1582	caryophyllene oxide	t	t	-	0.3	-	-
1586	gleenol	-	-	-	-	t	0.3
1587	trans-muurol-5-en-4-α-ol	-	-	-	t	-	-
1607	β-oplopenone	0.4	0.4	0.1	0.8	0.4	0.4
1618	1,10-di-epi-cubenol	t	-	-	-	t	0.2
1627	1-epi-cubenol	t	0.7	0.3	0.5	1.3	1.6
1630	γ-eudesmol	-	-	t	t	-	-
1638	epi-α-cadinol	0.7	0.6	0.3	0.6	0.4	1.1
1638	epi-α-muurolol	0.7	0.6	0.4	0.6	0.6	1.2
1644	α-muurolol	t	0.2	t	0.1	t	0.7
1649	β-eudesmol	0.4	t	0.2	0.2	-	-
1652	α-eudesmol	-	-	0.2	0.6	-	-
1652	α-cadinol	1.6	1.3	0.9	0.7	0.8	1.8
1675	cadalene	-	-	-	0.1	t	0.3
1687	43,167,81,238, unknown	-	-	-	0.3	-	-
1688	shyobunol	0.2	t	-	-	-	-
1739	oplopanone	t	0.2	-	0.2	-	-
1987	**manoyl oxide**	**t**	**-**	**-**	**t**	**1.0**	**3.2**
2009	epi-13-manoyl oxide	-	-	-	-	t	t
2056	manool	t	0.4	-	-	-	-
2055	abietatriene	t	t	-	-	-	-
2298	4-epi-abietal	t	0.2	-	-	-	-